THE HESSIAN FLY IN OHIO.

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DESCRIPTION OF THE HESSIAN FLY

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., DECEMBER, 1902

BULLETIN 136

EXPERIMENT STATION PRESS

The Bulletins of this Station are sent free to all residents of the State who request them. Persons who desire their address changed should give both old and new address. All correspondence should be addressed to

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The Bulletins of this Station are issued at irregular intervals. They are paged consecutively, and an index is included with the Annual Report, which constitutes the final number of each yearly volume.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 136. DECEMBER, 1902.

THE HESSIAN FLY IN OHIO

BY C. E. THORNE.

HISTORICAL.

The recent attack of Hessian fly exceeded in destructiveness in Ohio any previous attack of this insect of which we have a definite record. In the history of the Hessian fly, given in the Third Report of the U. S. Entomological Commission, it is stated that it was very destructive in Ohio in 1849; that it was reported in 1866, and was destructive and widespread in Ohio with other states in 1872 and 1873, 1879 and 1881 to 1883. Of these reported outbreaks, except the last, we find but little corroborative evidence in the reports of the State Board of Agriculture, and a study of the statistics of wheat production in connection with these reports shows that there was no general outbreak over the state. The destruction of the wheat crop in Ohio in 1866 was the most complete ever recorded until 1900, the average yield for the state falling below 5 bushels per acre and many counties failing to produce enough for seed; but the county reports for that year ascribe this destruction almost wholly to winter killing. A few correspondents mention the midge as aiding in the work, but only once is the fly spoken of,

and then as doing but little damage. The crop of 1872 was below the average in the middle and southern sections of the state, but the cause is generally ascribed to a dry fall and spring and severe winter. The Hessian fly is mentioned as one cause of the shortage in Noble and Shelby counties only. The average yield for the state at large in 1873 was 12.6 bushels, as against 13.4 bushels for the 10 years, 1870–79, and there is no evidence of any important attack by the fly. The average yield for 1879 was 17.8 bushels, or nearly 4½ bushels above the ten-year average, andthat of 1880 was 17.2 bushels. In 1881 the yield fell to 13.8 bushels, and in 1882 it was 15.6 bushels. This year 10 of the northwestern counties reported injury from the fly, and the yield of these counties is found to be from 1 to 3 bushels below their ten-year average. In 1883 the yield for the state fell to 10.7 bushels per acre, but the cause is generally ascribed to late sowing and winter killing. In only 10 counties, chiefly in the southwestern part of the state, is the fly mentioned as an important factor in the reduction of yield. The following extracts from the reports to the State Board of Agriculture for that year are of interest:—

ALLEN: "Wheat a failure from late sowing to avoid the ravages of the Hessian fly, the unusual severity of a part of the winter and a wet, cold, backward spring."

CLARK: "Wheat badly damaged by the Hessian fly in the fall of 1882 was illy prepared to meet the untoward influences of an inauspicious winter, and then he enfeebled plants were attacked by the May batch of this marauder from which they could not rally, reducing an average from 20 bushels per acre to less than 6 bushels of very inferior quality."

COSHOCTON: "Wheat half a crop. The great failure seems to have come from sowing too much wheat stubble, the Hessian fly, an unfavorable winter and the drought in the spring."

ERIE: "The growing wheat plants went into the winter of 1882–3 in fine condition. The early prospect for a good yield was seldom better, but protracted cold, cutting winds in January on the plants which were uncovered and unprotected by snow, followed by bitterly cold weather, froze the plants to death. The chief damage was done in January, and a cold, backward spring with severe east winds completed the work of destruction." (Similar reports were made from several northern counties.)

FAIRFIELD: "The average yield of wheat was not more than one-half other years, on account of injury done it by the flies in the fall and spring. The winter of 1882 was severe and the spring cold and backward."

GREENE: "The wheat crop was not more than 70 per cent. of a full crop, caused mostly by damage from the Hessian fly."

HARDIN: "The wheat crop was not an average on account of the fly."

MEDINA: "Many farmers sowed late in the fall of 1882 and their wheat had no chance to get well started for the hard and trying winter that followed, and the unfavorable spring was alike disastrous."

MORROW: "Wheat poor; cause, principally late sowing."

WAYNE: "The fall of 1881 was an exceedingly dry one. Many farmers did not get their wheat all in until about the first of October. The year was an exceptional one, and the late sowing was as good, and in some cases better, than that sown at the usual time, which in our county is from September 10th to 20th. This success of late sowing made the farmers careless, and much of the crop (for 1883) was put in the ground too late, not getting a fair start in the fall, and the after part of the winter being long and severe, much of the late sowing was a failure."

From 1884 to 1894 inclusive there was no complaint of fly in the state. The crop of 1885 was a very poor one, but its injury was everywhere ascribed to climatic conditions and not to fly.

In the spring of 1895 twenty counties in the southern part of the state reported injury from fly. That fall the presence of this insect was again noted, and the next spring 34 counties, lying in all quarters of the state, reported prevalence of fly. The average yield of wheat for the state fell to 11.6 bushels per acre in 1895 and 7.6 bushels in 1896, but the chief injury was ascribed to late seeding and unfavorable winter conditions, rather than to fly attack. In 1897 the average yield for the state rose to 16.15 bushels per acre and in 1898 it amounted to 15.56 bushels. In the fall of 1898 there was again some complaint of fly and in the spring of 1899 it was reported in most of the middle and southern counties; the average yield, however, reached 14 bushels for the state, notwithstanding the almost complete destruction of the crop by winter killing in some of the northwestern counties, where snow covering was deficient during the almost unprecedented cold of February. No fly had been reported in those counties.

MAP NO. 1—AVERAGE YIELD OF WHEAT IN OHIO IN 1899.
(Fly attack reported from counties marked x.)

Map No. 1, compiled from the final statistics of this crop as reported by the township assessors, shows the average yield of the different counties in 1899, the unshaded portion of the map indicating yields below 13 bushels per acre and the shaded portion above that amount. The counties from which Hessian fly was reported in June and July are indicated by (*x*). The destruction in the northwestern counties was altogether due to winter killing, no fly having been reported from that section. In the southern counties "white grub" is usually associated with fly as causing the injury to the crop, and in some cases is the only insect mentioned.

By December of 1899 the fly was reported from three-fourths of the counties of the state; unfavorable climatic conditions followed

MAP NO. 2—AVERAGE YIELD OF WHEAT IN OHIO IN 1900.

during the winter and spring; in June, 1900, the fly was again found generally prevalent, and the harvest proved to be the smallest, in average yield per acre, since the disastrous season of 1866, the yield for 1900 averaging but 4.4 bushels per acre for the state.

Map No. 2, also compiled from the assessors' reports, shows the average yield of wheat per acre for each county of the state in 1900, the unshaded portions indicating averages below 5 bushels per acre, and the shaded portions above that amount. It will be observed that the greatest destruction occured on the western watershed of the Miami valley and on the divide between the Miami and the Scioto. The largest average yield is found in the hill

counties of the state bordering the Ohio river, and this is much the largest relative yield, since the normal yield of these counties is but about 10 bushels per acre, against 12 to 14 bushels for the counties occupying the middle third of the state, and 14 to 16 bushels for those lying in the northern third.

Another group of counties showing relatively large yields is found in the northeastern section, in which Stark, Summit and Wayne lead with yields of 11 to 12½ bushels. There was, in fact, comparatively little injury from the fly in these counties, and throughout the crop season the superiority of their wheat to that of other districts was very evident.

A third area of superior yields is found in the northwestern corner of the state—the region most injured by the February freeze of 1899.

In the fall of 1900 wheat was sown very late all over the state, in the hope of avoiding another attack, and that this delay was justified is indicated by the numerous reports of injury to, or even complete destruction of early sown wheat, which are found in Secretary Miller's crop reports for November and December of that year and for January, 1901. Fly was reported that fall from more than 50 counties, lying in all parts of the state. At the Experiment Station it was more abundant than during the previous fall, and throughout Wayne county generally nearly as much damage was done, but over the state at large the injury was much less than during 1900. The frequent statements from all quarters, that early sown wheat was injured and that the greater portion of the crop had been sown unusually late, indicate that the compartive immunity of this season must be ascribed chiefly to late sowing.

The harvest of 1901 is indicated by Map No. 3. In this map the counties producing less than 13 bushels per acre are left unshaded, and it will be observed that the unshaded area includes most of the southern hill counties and also a group of counties lying in the middle of the state. The yields of the hill counties are not far from their normal product, but those of the middle counties are much below. A part of the reduction in these counties must be ascribed to chinch bugs, which were prevalent throughout much of this region.

MAP NO. 3—AVERAGE YIELD OF WHEAT IN OHIO IN 1901.

THE RELATION OF RAINFALL AND TEMPERATURE TO HESSIAN FLY ATTACK.

Table I indicates the departures from the normal rainfall and temperature in Ohio for August, September, October and November for the years 1881, 1882, 1883 and 1894 to 1901 inclusive. The Ohio State Weather Service was not established until November, 1882, and therefore the conditions for 1881 to 1883 are compiled from the reports of the U. S. Signal Service for the "Ohio Valley and lower lake region" for those years; the sign + indicating rainfall or temperature above the normal, — indicating deficiency in rainfall or low temperature, and (N) indicating normal conditions. From 1894 on the table is compiled from the reports of the State Weather Service.

TABLE I.—DEPARTURES FROM NORMAL RAINFALL AND TEMPERATURE.

Year	Section	Rainfall—Inches				Temperature—Degrees			
		Aug.	Sept.	Oct.	Nov.	Aug.	Sept.	Oct.	Nov.
1881	State. ..	—	—	+	+	+	+	+	+
1882 F	State. .	+	N	—	—	—	N	+	+
1883		—1.59	—0.91	+1.03	+0.25	—4.0	—4 0	+1.0	+1 6
1894	Northern .	—1.91	+1.09	—0.19	—0 43	+0.9	+3.3	+2 4	—3 1
	Middle . .	—1.40	+0 20	—0.43	—0.72	+0.5	+3.0	+2 0	—2 9
	Southern	—0.88	—0.17	—1.06	—1.28	+2.0	+3 7	+1.9	—2.4
1895 F	Northern .	+0.85	—0.68	—1.17	+1.59	+2.8	+4 2	—5 1	+0.4
	Middle ..	—0 19	—1.36	—1.25	+1.14	+2.7	+3.8	—4 6	+1.3
	Southern	—0.96	—1.49	—1.32	+0.37	+4 0	+5.1	—4 0	+1.10
1896 F	Northern	+0.23	+1.55	—1.37	—1.03	+1.3	—1 2	—2 7	+4.2
	Middle .	+0.09	+2.60	—1.31	—0.40	+0.7	—2 8	—3.4	+4.6
	Southern .	+0.55	+2.14	—0.84	+0.18	+1.3	—2.0	—1 8	+4.5
1897	Northern	+0.53	—1.90	—1.50	+2.78	—1.4	+2.1	+5.9	+1.1
	Middle ...	—0.71	—2.21	—1.58	+3.63	—1.6	+2.0	+6.5	+1 5
	Southern .	—1.84	—2.02	—1.78	+3.66	—0.1	+2 0	+6.7	+1.9
1898	Northern .	+1.60	+0.12	+1.99	+0.11	+2.2	+2.4	+2.0	—1.6
	Middle ...	+1.64	—0.42	+1.77	—0.42	+2.1	+2.5	+2.0	—2.0
	Southern .	+1.72	+0.18	+1.28	—0.33	+2.4	+2.6	+2 0	—1.8
1899 F	Northern .	—1.26	—0.06	—0.05	—1.03	+2.4	—1 6	+5.2	+3.2
	Middle ...	—1.27	—0.36	+0.10	—1.75	+2.9	—1.0	+5.0	+3.4
	Southern .	—0.73	+0.40	—0.03	—1.47	+2.2	—1.1	+4.7	+3.0
1900 F	Northern.	+0.95	—0.91	—0.32	+0.30	+5.3	+3.4	+8.0	+1.2
	Middle ...	+0.95	—0.63	—0.05	+0.30	+4.9	+3.8	+7.8	+0.5
	Southern .	+0.36	—1.24	—0.4	+2.04	+4.7	+4.5	+8.0	+1.0
1901	Northern .	+0.81	+0.28	—1.27	—1.49	+2.1	—0.1	+1.3	—2.6
	Middle ...	+0.54	+0.03	—1.54	—2.44	+1.8	—1.0	+1.5	—3.4
	Southern .	—0.40	—0.31	—1.46	—1.96	+1.3	—1.5	+1.1	—3.6

If we group the four months under consideration we see from this table that the general average conditions were as follows:—

	RAINFALL		TEMPERATURE		
1881			Above normal		Fly attack, ceasing with 1883.
1882	Below normal		"	"	
1883	Above	"	Below	"	
1894	Below	"	Above	"	
1895	"	"	"	"	Fly attack, ceasing with 1896.
1896	"	"	Below	"	
1897	"	"	Above	"	
1898	Above	"	"	"	Fly attack, ceasing with 1901.
1899	Below	"	"	"	
1900	Normal	"	"	"	
1901	Below	"	Below	"	

This table seems, therefore, to support the common belief among farmers that a warm autumn is favorable to the work of the fly. So far as the rainfall is concerned, however, we find but little support for any theory, as the attacks followed a dry August and September in 1881 and a wet August and a normal September in 1882; a dry August and September (over the southern portion of the state) in 1895 and a wet August and September in 1896; a dry August and September in 1899 and a wet August and a dry September in 1900.

The fact seems to be that the climatic conditions which favor the growth of the wheat plant also favor the increase of this insect parasite; for we find that the attack of 1881–3 followed a period of large yields, the average yields for the state being 15.6 to 17.8 bushels per acre for the four years, 1877 to 1880, whereas the 10-year average yield for the seventies was 13.4 bushels, and that of the eighties was 13.7 bushels. Again, the yields for 1891, 1892, 1893 and 1894 were 17.2, 14.6, 17.1 and 18.8 bushels per acre, and those for 1897 and 1898 were 16.1 and 15.6 bushels; while the 10-year average for the nineties was 14.6 bushels. As will be shown farther

on, it appears that the attacks of 1895–6 and 1899–1900 should be considered as a single attack, temporarily checked by the early frosts of the earlier seasons.

EFFECT OF FROST ON THE FLY.

Many farmers believe that a few sharp frosts will check the work of the fly and it would seem reasonable that such frosts, coming between the laying of the egg on the exposed surface of the leaf and the safe housing of the maggot at the base of the stem, might have such effect. The following are the dates of killing frosts of general extent in Ohio during the three periods of fly attack under consideration:—

1881—Oct. 5, 6, 7, 11, 12.
1882—Oct. 20, 21, 25, 30.
1883—Oct. 16, 17,
1884—Oct. 15, 23, 24, 29, 30.
1894—Oct. 14, 15, 18.
1895—Sept. 30, Oct. 1, 2, 3, 9, 10, 13, 18 to 26, 28, 29, 30, 31.
1896—Sept. 23, Oct. 8, 9, 18, 19, 21, 22, 24, 25.
1897—Sept. 21, Oct. 8, 18, 30.
1898—Oct. 27, 28.
1899—Sept. 30, Oct. 1, 2, 3, 7, 21, 22, 30.
1900—Oct. 17, 18, 19.
1901—Oct. 4, 5, 18, 25, 26.

The dates for 1882, 1883 and 1884 are those on which ice was reported by the U. S. Signal Service. Those for the subsequent seasons are those on which the State Weather Service reported minimum temperatures averaging about 32 degrees for the state. It appears from these records that the cessation of the fly attack of 1882–3 must be ascribed to some other cause than early frost, and that the attack of 1895–6 and 1899 occurred during seasons of early and severe frost. It will be observed, however, that after the first frosts of 1899 there was a period of about two weeks without frost and the weather records for the month show that the average temperature of the month was much above the normal, and this was followed by an abnormally warm November. In 1895 and 1896, however, there was no such intermission, and the October tempera-

ture for both years was below the normal. In 1901, as will be shown farther on, there was a definite cessation of egg laying, in the experiments under the writer's observation, coincident with the first appearance of severe frosts. These frosts, like those of 1899, were followed by a similar period of warm weather, and the average October temperature was again slightly above the normal, but this was followed by a cold November; and while I was able to find living larvæ of the fly at the end of October and during November, they were few in number as compared with the multitude of eggs which were observed before the frost.

In view of these observations it seems probable that the attack of 1895 and 1896 was checked by the continuous October frosts of those seasons, but that enough flies escaped to be able, with the aid of the weather conditions of 1897 and 1898, to again re-stock the fields for the disastrous attack of 1899 and 1900. For the final cessation of the attack, over the state at large, we are no doubt indebted to the same agencies which brought to an end the attack of 1882–3, and which are believed to be chiefly the increase of secondary parasites, working upon the fly itself. Such parasites are known to exist, and it is easy to understand that, as their existence depends upon that of their hosts, the causes which restrict the numbers of the flies must also reduce the number of parasites, while conditions favoring the multiplication of the host may enable it for a few seasons to escape from the control of the parasite, only finally to be overtaken again by the latter. To fully account for all the facts observed we must assume that while the conditions which favor the increase of the host must, in a general way, be the same as those which encourage the multiplication of its parasite, yet there must also be minor conditions more favorable to the one than to the other, an assumption justified by the familiar example of wheat rust: the warm, moist weather which encourages the growth of this parasite is also favorable to the growth of the wheat at an earlier stage, and becomes detrimental only as the time for the ripening of the wheat approaches.

Frost, however, is beyond human control, nor can we predict its coming sufficiently far in advance to be of any service to us in this matter. The chief value of exact knowledge on this point would be to enable us to judge, when the frost has actually come, as to its probable effect on our crop. Such knowledge would often be useful and attention is called to the matter here in the hope of enlisting more careful observations in the future.

EFFECT OF FERTILIZERS ON THE FLY.

We are often asked what effect fertilizers, manure and lime have on the fly, to which we are forced to reply that we have observed none. In the fall of 1899, the wheat in the fertilizer tests at this Station was carefully examined by the then Assistant Entomologist, Mr. C. W. Mally, who reported more fly on the fertilized plots than on those receiving no fertilizers. One half-acre of wheat was that fall treated with slaked lime, applied to the surface, just before sowing the wheat, at the rate of 1000 pounds per acre. This half-acre showed quite as much injury from the spring attack of the fly, the following spring, as the unlimed half-acre adjoining. In examining our wheat, early in April of 1901, the writer found the unfertilized wheat at Strongsville almost totally destroyed by the fly, the drill rows being filled with dead plants, each of which harbored the well known "flax-seeds." On the fertilized plots alongside about half the wheat was left; so that the injury, while apparently greater on the unfertilized plots, was really about the same under both methods of treatment. In other words: where we have used manure or fertilizers we have saved some wheat, notwithstanding the fly; but the actual fact seems to have been that the greater care taken in preparing the land and sowing the wheat, the larger was the amount of provender furnished the depredator.

EXPERIMENTS ON DATE OF SOWING WHEAT.

In 1878 experiments were begun by the Farm Department of the Ohio State University at Columbus in sowing wheat on different dates, one of the objects of these experiments being to obtain data bearing upon the relation between date of sowing and injury from fly. These experiments were continued for two years by that department. After the establishment of the Experiment Station and its location on the University Farm they were resumed by the Station, and have been continued, first at Columbus and later at Wooster, but with several intermissions, up to date; this work since 1888 having been conducted under the immediate supervision of the Agriculturist of the Station, the late Mr. J. Fremont Hickman. The general outcome of these tests is shown in Table II.

TABLE II.—YIELD OF WHEAT IN BUSHELS PER ACRE FROM DIFFERENT DATES OF SOWING.

Place and year of harvesting	Date of Sowing										
	August		September				October				Nov.
	22-25	29-31	6-10	13-17	20-24	27-30	4-8	11-15	18-20	25-27	1.
Columbus:											
1879			33.2	30.3	36 4	32.7	26.2				
1880			32 5	33.0	33.5	29.5	26.2				
1883*a*	24.1		34.9		34.2		34.7				
1883*b*		40.0		42.4	44 7	47.1		38.0			
1884	35.8	51.8	55.6	57.2	53.2	54.6	56.9	44.4	43.6	35 6	
1886		41.2	32.3	35.0	38.6	42.1	36.5	38.0	29.9	18.9	
1887	31.7	31.6	28.3	31.3	27.8	26.1	32.7	30.6	20.9		7.4
1888	12.8	11 2	12.1	26.6	26.6	26.1	28.2	33.0	20.8	27.7	22.9
1889			34.9	26.9	27.4	42.4	47.3	33.8			42.0
1890	16.8	16.8	19.1	20.2	20.9	22.5	26.5	22.6	23.0		25.0
Wooster:											
1895			8.5	7.6	8.1	5.0	5.7	5.7	5.0	2.3	
1899		18.0	18.3	25.5	23.5	22.8	21.5	19.3	11.2		
1900					13 7	16.7	15.7	10.4	8.0		
1901		9.8	5.5	5.7	2.0	14.0	19.5	19.8	11.7	11.7	
1902		25.0	26.8	25.5	28.3	25.5	25.5	22.2	15.5	9 3	
Strongsville:											
1901		21.9	20.3	17.7	22.0	24.7	22.2	22.9			

The experiments of 1878–9 and 1879–80 were made on bottom and of very superior quality. In the latter season duplicate plots were sown at each date. In 1878–9 the first and second sowings were slightly injured by the fly in the fall. In 1879–80 no such injury was observed.

In 1882–3 the experiment was made in duplicate on different soils. The sowing of August 25th showed injury from the fly by October 1st, and it was estimated that about one-fifth of the plants

were infested and 12 to 15 per cent destroyed. The plot sown September 8th was slightly infested, but no fly was found on the plot sown September 1st on better land. None of the later sown plots were attacked, and the flies were much less numerous the following June.

In 1883–4, the plot sown August 25th was attacked by the fly, and it was estimated that 10 per cent of the plants were destroyed. A very few larvæ were found in the sowings of September 1st and 8th, and none in the later sowings.

In 1884–5, the entire crop was destroyed by winter killing.

In 1885–6, none of the plots showed any injury from fly, and from this time to the end of the tests at Columbus the variations found in the different seedings must be ascribed to other causes than the ravages of this insect, as no fly was observed at the Station, nor did any complaint come in regarding it from other sections of the State.

It appears from these experiments, therefore, that there was no serious injury from Hessian fly in that region during the eleven years covered by the tests, on any wheat sown later than September 1st, and that, under such immunity the largest crops were generally harvested from wheat sown during the last two weeks of September and the first week of October.

Taking up the northern Ohio tests, we find that in 1894–5 and 1898–9 the largest yield came from wheat sown between the 8th and 22nd of September; but with the advent of the fly in destructive numbers this period proved to be the one of greatest injury. The earlier sowings in this test were omitted in the fall of 1899, but wheat sown before the 20th of September in other work and on adjoining farms, that fall, was generally infested with the fly, although there was no case of complete destruction in the neighborhood.

In entomological publications of this Station, issued prior to 1900, it has been assumed that the adult Hessian flies of the fall brood develop and disappear, in the latitude of this Station, by September 20th, and in that of the test farm at Strongsville, 40 miles north, by September 15th. The attack of 1899–1900, however, reached its most destructive force on wheat sown on precisely the dates which had been published as safe. This was explained on the theory that the drought, which prevailed over the state during August and the first half of September, had retarded the emergence of the adult flies. During the period between August 20th and September 9th, 1900, both inclusive, there fell at this Station more than 5 inches of

rain, and at the sub-station more than 3 inches, which would seem to have been quite enough to bring out the fly at its normal period, and therefore we began seeding the general crop at the sub-station on September 18th, and at the central Station on the 24th, thus taking a margin, beyond the dates given as safe, of three or four days in each case.

The wheat sown on this date at Strongsville was on areas devoted to fertilizer testing, in which every third plot is left continuously unfertilized. In going over this wheat in April, the drill rows on the unfertilized plots were full of dead wheat plants and in every plant were found the "flaxseeds" of the fly. On the fertilized plots some wheat was left, but there also it was evident that the pest had been industriously at work. The harvest showed an average yield of less than two bushels per acre on the unfertilized plots, and of ten bushels and under on the fertilized plots, as against an unfertilized yield of five to nine bushels and a fertilized yield reaching twenty to thirty bushels on similar land in the same series of experiments sown a week later.

At Wooster the earliest sown wheat was in the variety test, a tract of nearly twelve acres, which had been plowed in August, then top-dressed with barnyard manure and prepared in every way with the utmost care. At the beginning of April the plants seemed to have been more than half destroyed, but the favorable weather strengthened the growth and the harvest produced an average yield of about sixteen bushels. as against twenty-five to thirty bushels on lands similarly treated but sown one to two weeks later. At both places the wheat followed oats.

At both places experiments were made in sowing at different dates, beginning August 31st at Wooster, and September 1st at Strongsville, and continuing at weekly intervals until the end of October. This test at Wooster was made on unfertilized land; at Strongsville on land which had received an ordinary complete fertilizer, used at the rate of 300 pounds per acre. The results of the harvest are shown in Table II.

At Wooster the plot first sown was attacked in the fall by rust, which seems to have been the chief cause of the reduced yield of this plot, as it was at no time seriously infested with the fly. Both rust and fly were found on the second and third plots. The plot sown September 21st showed little, or no rust, but was almost completely destroyed by the fly; that sown September 28th received less injury from the fly, while those sown after this date were injured only by the spring attack of fly. There was no rust of con-

sequence on any wheat sown after September 14th. During the spring the earliest sown plot appeared to be one of the best in the series; its relatively lower yield seems to have been in part due to failure to fill properly.

At Strongsville there was no fall rust. In April the injury to the sowings of September 14th and 21st seemed almost as great here as at Wooster, but the fertilizer used here apparently enabled the wheat to overcome this injury to a greater extent, so that the final differences are less marked here than at Wooster. In both cases, however, the destructive work of the fly reached its climax on wheat sown September 21st and 22nd, the sowings of these dates suffering more than those of earlier or later date, and on this point we have the testimony of many farmers that in both seasons early sown wheat was less injured than that sown at a later date.

The following extracts from letters received at the Station about the first of August, 1901, throw some light upon the general question under discussion:—

"None of my wheat was hurt by the fly except some sown September 28th, which was a very litle. Wheat sown Oct. 2nd was all right."

H. A. Starn,
Rittman, Wayne County.

"I drilled my wheat September 22nd to 24th, a week too early to escape the fly, and it did considerable damage in the fall."

T. G. Stence,
Ashland, Ashland Co.

"We sowed on September 17th, which proved at least two weeks too early for our locality this year, all our wheat sown that early being almost totally destroyed by the fly."

H. Markley,
Chesterville, Morrow Co.

"We did not sow wheat until October 11th to 16th. We could not find any fly in our wheat last fall or during the winter, but we have lots of it this spring."

C. H. McCormick,
McCormick, Gallia Co.

(This report is valuable as showing the earliest date of safety in extreme southern Ohio, as wheat sown earlier in October was injured by fly in some localities.)

These expressions confirm the Station's experiments in showing that the fly made its appearance quite as late after the copious rains of August and September, 1900, as after the drought of the same period in 1899.

The accompanying illustrations show the appearance of the plots in the test at Wooster at the beginning of April, 1901.

This experiment was repeated at both the main Station and the sub-station in the crops of 1901–2, and 1902–3 the sowings being made on the same dates as during the previous season. On September 25th, 1901, at Wooster, I found the fly depositing eggs on the young plants from the sowings of August 31st, September 7th and September 14th. All the sowings were infested with eggs, but much the larger number were found on the tender, single spears of the latest sowing, and more on that of September 7th than on that of August 31st. On September 27th the wheat sown September 21st appeared above ground and the inch-long shoots were at once made the receptacles of the parasites' eggs.

On the afternoon of the 28th there fell 2½ inches of rain, and on the 30th it was difficult to find either flies or eggs. My notes say: "scarcely one egg to twenty before the rain," but the next day fresh eggs were found on all the sowings, their presence on plants which had come through the ground since the rain showing that the flies had not all been destroyed. These later eggs were found on all the sowings, but more frequently on the last two.

On wheat plants sent from the sowings at Strongsville, I found a few eggs on the sowings of September 1st, 8th and 15th. None were found on the sowing of September 22nd. The last examination of these plants was made October 5th, and while almost half the plants from the sowing of September 15th were found infested, the eggs were all on the first leaf, indicating that egg-laying had ceased some days before.

The first frost sufficient to affect corn came on the night of October 3d, and this was followed by nightly frosts until the 7th. Door-yard plants were frozen under muslin covers. Egg-laying seems to have ceased with these frosts, as I found no eggs on wheat sown later than September 25th.

On October 25th, I found nearly full grown larvæ of Hessian fly in wheat sown August 31st and a few small larvæ, (some still retaining the red color of the egg,) in the sowing of September 21st but they were not abundant. Neither in April nor in June of 1902 have I been able to find any sign of Hessian fly in in the Station wheat, and we have had no report of its appearance in any other part of the State; hence it would seem probable that there will be a temporary relief from its devastations.

The experiment in sowing on different dates was repeated at the main Station again last fall. The first half of September was cool and dry, and the earlier sowings were slow in appearing above the surface. I examined them carefully from time to time, finding

no eggs up to September 21st. On the 22nd I found a few eggs, and on the 23rd they were more numerous. I then turned over the work to Mr. P. J. Parrott, Entomologist of the Station, who furnishes the following notes:

OBSERVATIONS OF THE HESSIAN FLY FOR 1902.

PLOT I Sown Sept. 1st, appeared Sept. 11th.
PLOT II Sown Sept. 8th, appeared Sept. 19th.
PLOT III Sown Sept. 15th, appeared Sept. 22nd.
PLOT IV Sown Sept. 22nd, appeared Sept. 25th.
PLOT V Sown Sept. 29th, appeared Oct. 2nd.

Examined volunteer wheat well on Sept. 13th and could find no traces of eggs.

On Sept. 22nd, Director Thorne found few specimens of eggs upon Plots I and II, more on II than I. This was my experience also. In the afternoon examined young wheat in Plot III without finding an egg. Ground was wet from rains the day before.

Sept. 23rd examined plots and found eggs more numerous, and more easily to be found apparently on Plot II. To ascertain the daily increase in the number of eggs, I staked off on Plot II, 229 plants; Plot III, 253 plants; Plot IV, 110 plants, and made the following observations upon the number of eggs deposited for each day from Sept. 23rd to Oct. 3rd.*

DATE	PLOT II	PLOT III	PLOT IV
Sept. 23rd	3 eggs to 229 plants	6 eggs to 196 plants	
" 24th	2 " " 229 "	6 " " 253 "	
" 25th	6 " " 230 "	3 " " 241 "	
" 26th	3 " " 232 "	2 " " 254 "	
" 27th	3 " " 256 "	0 " " 251 "	2 eggs to 110 plants
" 28th			
" 29th	0 " " 256 "	0 " " 251 "	0 " " 110 "
" 30th	1 " " 256 "	0 " " 251 "	2 " " 110 "
" 31st	0 " " 256 "	0 " " 251 "	0 " " 110 "
Oct. 1st	0 " " 256 "	0 " " 251 "	0 " " 110 "
" 2nd	0 " " 256 "	0 " " 251 "	0 " " 110 "
" 3rd	0 " " 256 "	0 " " 251 "	0 " " 110 "
" 4th	0 " " 256 "	0 " " 251 "	0 " " 110 "

* Each day picked off leaf to which egg was attached.

These notes show that the attack was a very light one, and that egg-laying was practically limited to the week between September 22nd and 28th. Referring to the dates of sowing and of appearance of the wheat above ground it will be seen that the sowing of Sept. 22nd came through the ground within four days, its germination and growth having been hastened by warm, rainy weather. Under such conditions the latest sowing which could have received the eggs of the fly this season would have been September 24th, a date corresponding to our previous experience, while the number of eggs counted on the different sowings indicate that, had the flies been abundant, the greatest injury would probably have

fallen this year as before, upon wheat sown between September 8th and 22nd.

HOW LATE MUST WHEAT BE SOWN TO AVOID THE FLY.

The distance between the northern and southern limits of Ohio is about 240 miles. The sun travels over the distance between the tropics at a rate of about 17.8 miles per hour, but, owing to the curvature of the earth, the time required to cross Ohio is less than twelve days. How far the average season lags behind the sun we do not know. There is great need of systematic observations over the state upon such natural phenomena as the opening of leaves and flowers in the spring and coloring and falling of leaves in the fall. One of the easiest phenomena to observe and record would be the dates of wheat ripening throughout the state, but even on this point no data, collected with sufficient care and through a sufficiently long period of time to serve as a reliable basis of calculation, are available.

In regard to the date of wheat seeding, local custom and individual situation and experience have much to do; so that if one were to traverse the state from north to south he would find wheat-sowing in progress throughout September and well into October in the average season. If, however, it were possible to collate the average custom of the most intelligent and careful farmers it would probably be found that the real difference in the time of seeding by most farmers, between the northern and southern limits of the State, does not exceed two weeks. In other words: few such farmers sow before September 15th along the lake shore, and few later than October 1st in the river counties, when seasonal conditions are such as to permit free choice of date.

Judging from our experiments and the information received from others, it appears that the earliest date at which wheat could safely be sown in extreme northern Ohio in 1900 and 1901 was about September 23rd; at the Station about September 26th; at Columbus about October 4th and in the river counties about October 10th—a range of between two and three weeks for the entire state.

In the report of the Michigan Board of Agriculture for 1877 appears a paper by Prof. A. J. Cook, then Professor of Entomology in the Michigan Agricultural College, in which is given the history of an attack of Hessian fly then culminating in Southern Michigan, together with a most valuable account of the habits of the pest and suggestions for preventing its ravages. In this report Professor Cook states that wheat sown after September 20th in that latitude has usually escaped the fly, but that in 1877 this date proved not to be sufficiently late, several reports having come to him of wheat sown as late as September 20th being full of the

insects. On this point Professor Clinton D. Smith, Director of the Michigan Experiment Station, informed the writer early in the spring of 1901 that wheat sown September 20th the preceeding fall, in the experimental sowings of that Station, was badly injured by the fly.

It appears, therefore, that destruction by the Hessian fly of wheat sown as late as September 20th in southern Michigan is not a new thing, and that we must expect a still later date as being the earliest date of probable safety for northern Ohio.

DESCRIPTION OF THE HESSIAN FLY.

The Hessian fly is about half the size of a mosquito, which it considerably resembles in appearance. It belongs, in fact, to the same insect family as the mosquitos and gnats. Farmers send us a great many crane flies, supposing them to be Hessian flies, and others speak of seeing swarms of Hessian flies over their fields, but it is probably these crane flies which they see. This crane fly is half an inch or more in length of body and more than an inch across the wings, being many times larger than the Hessian fly. Its eggs produce maggots which feed on the roots of wheat and grass, but it has not been known to cause very great injury to the crop.

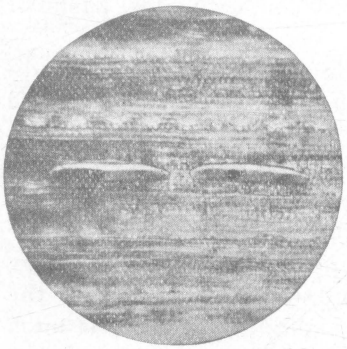


FIG. 5. Eggs of the Hessian Fly. (Magnified 30 diameters.)

When the Hessian fly is engaged in egg-laying it may be seen to fly from the ground to the wheat plant, deposit its egg, or eggs, and then return to the ground again, the whole operation requiring but a fraction of a minute. The egg appears to the unaided eye as a minute, reddish speck; when viewed with a magnifier it is seen to be elongated oval in shape. It is about one-fiftieth of an inch in length and seven times as long as wide. Fig. 5 is a microphotograph of a pair of Hessian fly eggs, magnified 30 diameters or 900 times. Frequently two or more eggs are laid at once, end to end, and sometimes we find two or more rows of eggs side by side. The eggs are laid in the creases of the leaf and preferably, though not invariably, on the youngest plants to be found.

FIG. 6. Young wheat plant, first week of growth.

The accompanying illustrations show young wheat plants of various ages, taken from our sowings of different dates. Fig. 6 shows the single spear of the plant during the first week of its growth. It was on these spears in 1901, from wheat that had been sown September 21st, that I found the greatest number of fresh eggs, although there was wheat close by that had attained the sizes shown in Fig. 8, 9 and 10. As the plants grow this first spear soon turns down, as shown in Fig. 7, and the eggs, which are laid in the creases of the inner surface of the leaf, now appear to be upon the upper surface and a casual observer would assume that they had been thus deposited after the leaf had turned out and down. Some eggs probably are deposited under such circumstances, but usually the observer who finds them in this situation may safely assume that it has been several days since they were deposited.

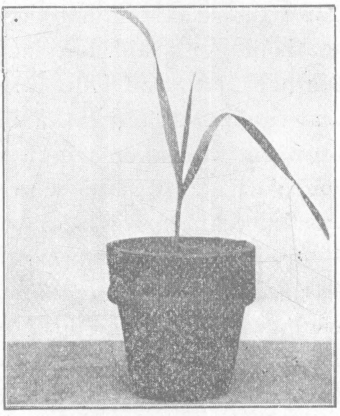


FIG. 7. Young wheat plant, second week of growth.

According to entomologists the egg hatches in from four days to two weeks—the shorter period being given by Dr. Harris as the usual time required for hatching in warm weather—and the newly hatched maggot, or larva, still reddish colored, crawls down between the sheath of the outside leaf and the stem until it is stopped by the lower joint, where it establishes itself a little below the surface of the ground and begins to suck the juices of the plant. As the larva grows it loses its reddish color, first becoming white, then showing a dark spot in the middle of the back, which gradually extends over the entire surface, and in four to six weeks it has attained approximately the size, color and shape of a flaxseed, being somewhat smaller and a little more elongated. This "flaxseed" consists of a thin, hard shell, within which the maggot undergoes its transformation into the winged fly, in which form it emerges late in

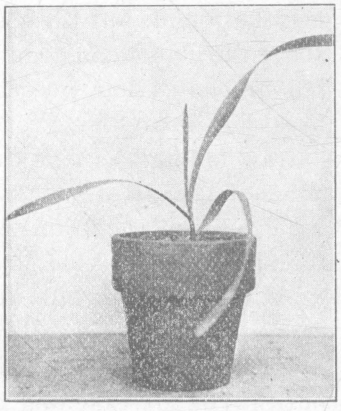


FIG. 8. Young wheat plant, third week of growth.

April or early in May, the following spring, ready to produce another brood.

On the 25th of October I found nearly grown larvæ on wheat sown August 31st, and small larvæ, some still retaining their reddish color, on wheat sown September 21st. These last must have come from eggs laid between September 27th and Oct. 3rd. At that time, October 25th, the photograph was taken which is shown in Fig. 12 and which shows two nearly grown larvæ, not yet having the flaxseed color but showing the dark spot. These larvæ had fastened themselves to the earliest spear of a wheat stool, and had sucked its juices until it had shriveled away; but a new stem had started up from the same stool and would have made a strong plant, while a third stem, shown on the right side of the picture, was just pushing its way through the ground, its curled tip not yet having reached the light. This photograph shows how a vigorous plant may overcome the attack of the parasite under favoring weather and soil conditions.

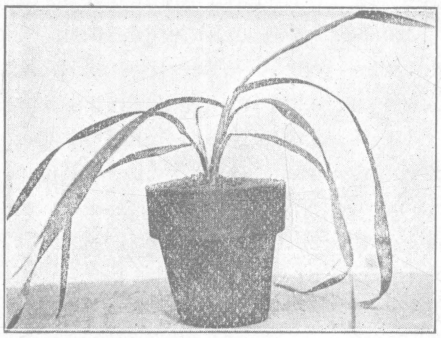


FIG. 9. Young wheat plant, fourth week of growth.

A short time before harvest the "flaxseed" of the spring brood may be found, but these spring flaxseed are usually located a little above the ground, instead of below the surface as in the case of the fall brood. Their presence will be first indicated by the wheat breaking near the ground—"straw falling" as it is called. When the heads of such wheat are examined, the grain will be found to be shriveled.

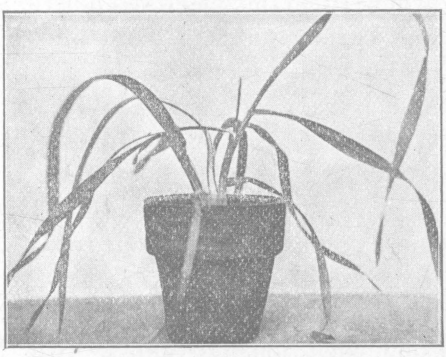


FIG. 10. Young wheat plant, fifth week of growth.

Usually the fall attack causes the greater damage, by either killing the plants outright or so weakening them that they fail to live over winter: but sometimes the spring attack is also a serious matter. In the spring, as in the fall, weather and soil conditions may to some extent affect the plant's ability to resist the attack.

On September 28th, 1901, I received volunteer wheat plants from R. L. Holman, of Springfield, which contained the "flaxseeds" of the Hessian fly. This was a full month before I was able to find similar flaxseeds in the wheat at the Station, and indicates either a considerably earlier appearance of the autumn brood at Springfield than at Wooster, or else the work of an intermediate brood. Such cases have been noticed before, but the matter has not been thoroughly worked out.

CONCLUSION.

From the foregoing study of Hessian fly outbreaks in Ohio it seems that the two factors which conduce most to such outbreaks are a scarcity of the parasites which hold the fly in check and a warm October, and these factors must work in conjunction. It does not appear that ordinary conditions of lack or abundance of rainfall play an important part.

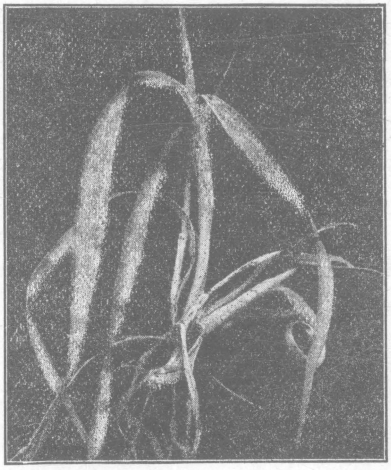


FIG. 11. Young wheat plant infested with larvæ of Hessian fly.

From an entomological standpoint it is possible to avoid injury from the fly by very late seeding; but in average seasons the risk of winter injury to wheat sown sufficiently late to avoid the fly appears to be quite as great as the risk from the fly.

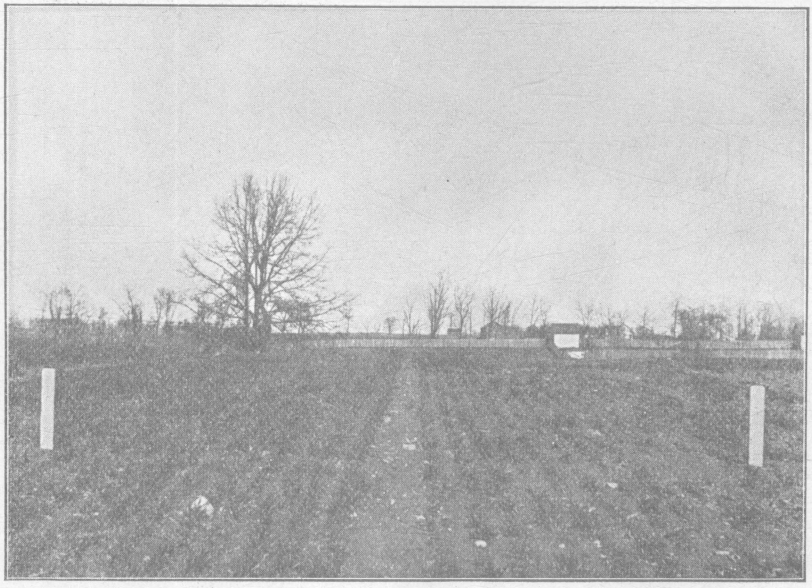
Neither manure, fertilizers nor what is known as good husbandry seem to have any effect in reducing the ravages of the fly. On the contrary, the better the conditions under which the seeding is done the more wheat plants are placed at the disposal of the fly. It is true, however, that when the seeding is deferred to a late date careful preparation and fertilization of the soil will do much towards enabling the plants to endure the winter.

The more practical method of combating this pest would seem to be, when danger from fly is apprehended, to sow a part of the crop at a moderately early date—say from about September 5th in the lake shore counties to about the 18th along the Ohio River—then watch the young plants closely for the minute, reddish eggs of the fly. If none are found when the plants are ten to twelve days old, sow the remainder of the crop; but if the young

plants are found to be considerably infested, wait another week before sowing.

Another method which might commend itself to some would be to make several sowings, a few days apart, in the hope that some of these would draw the main attack of the fly, and thus save the others. It has been repeatedly observed that wheat sown one day may be severely injured by the fly, while that sown the next day may escape; the apparent explanation being that the first sowing has drawn the full force of the fly attack and thus protected that sown later. For this outcome to be realized it is evident that the first sowing must be large enough to furnish plants enough for all the flies. We have not observed that the one-tenth acre plots used in our early and late sowings had any appreciable effect in protecting the large fields adjoining. The practical farmer would much rather lose all the wheat on one-third of his acreage than to lose one third of the wheat on all his acreage; and if by sacrificing a part of his crop in this manner he could save the remainder, he would gladly do so.

Either of these methods offers the great practical advantage that in case of a fall infestation becoming evident the wheat can be turned under and thus the spring brood of flies materially curtailed.



Sown August 31. Sown September 7.

FIGURE I.

Sown September 14. Sown September 21.

FIGURE II.

Sown September 28. Sown October 6.

FIGURE III.

Sown October 6. Sown October 12.

FIGURE IV.